Role of Y chromosome in Sex-differentiation through human development

Lina A. Salih
Department of Biology, College of Science, University of Baghdad, Baghdad, Iraq
Lina_salih2011@yahoo.com

Key words: Y chromosome, sex differentiation, evolution,

Abstract
The sexual characteristics character of a one is the last result of hereditary, morphologic sex and hormonal. The determination sex of male has been associated to the existence of the Y chromosome, has karyotype sign of the male gonads. Still, researches have delivered documents to influence it, this model is only part of the reality. The Y chromosome, an assembly of additional genes impact gender determination the origin of male to female sex-shift and opposite. It is of unlimited attention that genetic materials are set in extra than one somatic chromosome or in the X chromosome. It has developed understandable that determination of sex, agreeing to the genetic sex, is a complex problem that not only wants the existence of Y chromosome. This discovery prompted extensive research on the Y chromosome facts, providing significant insights into the structure, origin, evolution, and eventual fate in future of humans.

Introduction

Sex Chromosomes

Sex determination leads to the development of individuals with distinguishing characteristics that categorize them as male, female, or, in certain cases, hermaphroditic. in some animals. For some species (e.g., the solid nematode C. elegans), sexual difference may take the form of very small morphometric differences between sexual traits; in fact the only sexual characteristic that can be used to distinguish the two sexes in C. elegans is their testis (versus ovo-testis) [17]. In other species the differences between the sexes can be very pronounced. Take the elaborate plumage and display of a tom turkey, for example, versus the relatively drab features of a female turkey. You can easily tell female and male mammals apart by. (1)
The early 1900s marked the first significant advancement in the comprehension of sex determination with the identification of sex chromosomes. Through detailed examinations of the chromosomes in male and female insects, researchers found that while the majority of chromosomes appeared in equal quantities in both sexes, one or two chromosomes were present in differing amounts between males and females. Over the years, studies of various species have shown that these chromosomal variations are largely accountable for sex determination in the majority of animals. (2)

Biological bases of sex determination in human

As in other mammals the humans, the process of determination of sex occurs in two stages: primary determination and secondary determination. The first stage, primary sex determination, involves the formation of reproductive organs—either the testis or the ovary—which are the organs that generate gametes (sperm and egg cells, respectively). Following this, secondary sex determination is influenced by the hormones released from the gonads: in females, estrogens produced by the fetal ovaries promote the development of the uterus, oviducts, and cervix, while in males; the

hormones from the testes (including anti-Müllerian duct hormone, testosterone, and dihydrotestosterone) facilitate the emergence of male characteristics. as shown in (Fig. 1). Ultimately, beginning with embryonic development, the synthesis of sex hormones is carefully controlled throughout an individual's life and significantly influences bodily growth and function. (3)

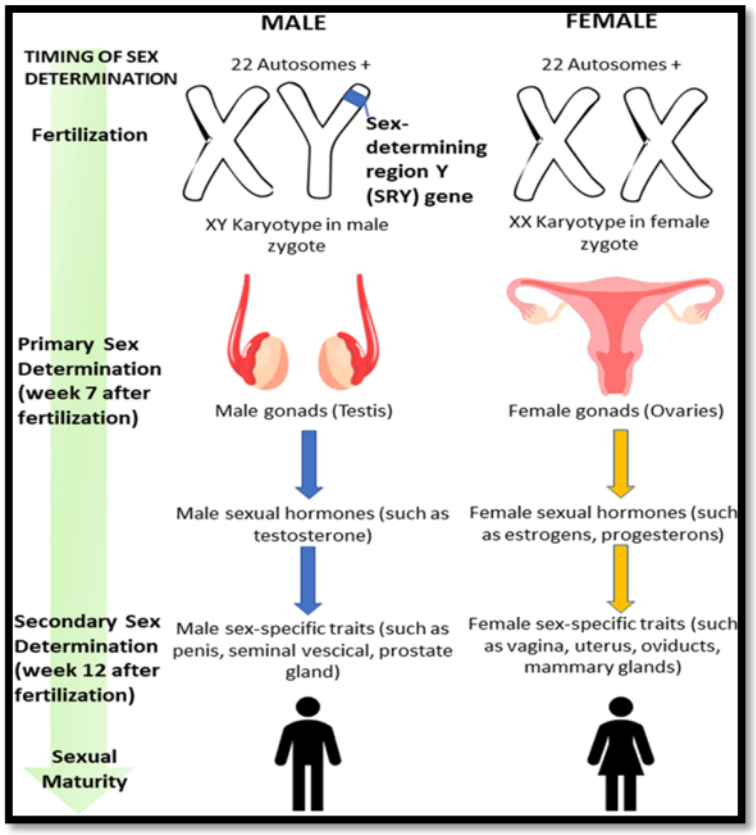

Figure (1) Biological base of sex determination in humans. (3)

Biological structure of Y chromosome

The karyotype of mammals contains the sex chromosomes, X and Y; called the gonosome one of these is Y chromosome, it's the smallest chromosome in the karyotype, and containing between roughly 70 and 202 genes. (3).as shown in figure (1). This small chromosome is proper for studying the biological evolution and biodiversity in animals, male infertility and/or subfertility because its distinctive structures such as long not-recombining sites (4)

The mammalian males considered a heterogametic phenotype which mean the sperms bearing equal proportion of X- and Y-chromosomes, while the females are homogametic because all ova are X-bearing. It was establish that Y chromosome has high repetitive sequence of DNA, which consists of pseudogenes without any functions (5)

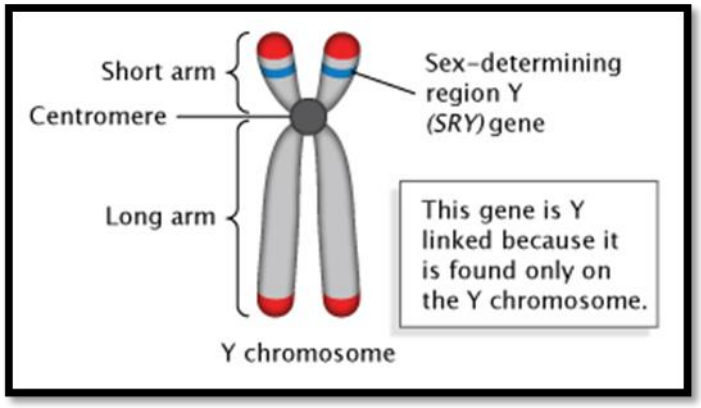

Figure 2: SRY gene on the Y chromosome.

Within different species of animals,Y chromosome found in different forms with dimensions. In humpless-cattle (*Bostaurus*), it is a slight sub metacentric, whereas in humped zebu (*Bosindicus*), it is a small acrocentric with detectible small p-arm ("p" for "petite," means small); in river buffalo (*Bubalusbubalis*), it is a small acrocentric chromosome, while in both sheep (*Ovisaries*) and goat (*Capra hircus*), it is very small and metacentric . duplication structures of Y-chromosomes studied to associate with many sperm analysis parameters (6)

Evolutionary concepts of Y-chromosome

Typically Y chromosomes are originate from X chromosomes within a process of degeneration and loosing of some genes, the origin of Sex chromosome from an autosomal chromosome through a three-step process which begins with the achievement of one or more strong sex-determining genes by one autosome, giving rise to embryonic X and Y chromosomes. During evolution, many holandric genes were deleted. The infertility and/or subfertility problems due to some mutation means may be deletion of the Y chromosomal genes have also been discussed. (7) Genetic sex determination with otherwise homo-morphic sex chromosomes is experimental in many taxa in amphibians, fish, reptiles and many invertebrates, the evolution of the human Y chromosome has been shaped by several key evolutionary forces, including natural selection, meiotic dynamics, and gene conversion processes. These forces have contributed to the complexity and diversity observed in the Y chromosome, influencing its structure and function over time. (8)

The specific genes on the Y chromosome that trigger sex-differentiation in human

The Y chromosome plays a crucial role in human sexual category differentiation, primarily through the action of specific genes that initiate and regulate the development of male appearances. The most important gene is SRY , the master switch for male sex determination, which triggers a cascade of genetic events leading to testis formation this gene initiates the differentiation of Sertoli cells, crucial for testis development, It promotes the expression of Sox9, which is critical for Sertoli cell differentiation, leading to testis morphogenesis (9) , **SOX9**: is a target of SRY that further drives the differentiation of Sertoli cells, which are vital for testis development ,that further promotes Sertoli cell differentiation and testis morphogenesis, SRY's activation of Sox9 reinforces male differentiation while inhibiting ovarian development pathways , **FGF9**: Involved in the maintenance of testis development and **AMH**: Anti-Müllerian hormone, which avoids the

embryogenesis of female reproductive structures , these genes collectively ensure the proper formation and maintenance of male gonads, highlighting the complexity of sex differentiation. (10)

The Y chromosome contains additional genes that contribute to male-specific effects beyond gonadal development, influencing various biological processes While SRY is the primary gene responsible for initiating male differentiation, the interplay of other Y-linked genes and their regulatory networks is essential for the complete development of male characteristics. However, it is important to note that variations in these genes can lead to disorders of sex development, highlighting the complexity of sex differentiation mechanisms. (11)

Interaction between hormonal control and Y chromosome during sex-differentiation

Many aspects of reproduction and fertility facts in many animal groups are controlled by hormones secreted by the gonads ; ovaries and testes, the production and secretion of reproductive hormones serve the development of sexual phenotypes during embryogenesis, sexual maturation at puberty, and several types of sexual activities ; sex energy and potential, sexual behavior, and, in some species, traits such as strength, the drive for control, and parenting within family behavior **(**12 **)**

Hormonal factors, particularly androgens and estrogens, play a vital role in regulating sex development, interacting intricately with the Y chromosome. The SRY gene initiates male sex determination, leading to the development of testes that produce androgens like testosterone. This hormonal environment is essential for male genital differentiation and influences brain development. Conversely, estrogens primarily produced in females, also impact development, highlighting the complex interplay between these hormones and genetic factors. (13)

Is Y chromosome may disappear in the next few million years?

The Y chromosome reduction is a route called chromosomal deterioration, occurs when definite DNA segment on the chromosome develop dismissed or broken, leading to their final loss. Y chromosome is subject to this state because, changed other chromosomes, it doesn't undergo to the genetic recombination in the same chance to all chromosomes on it, this may supports the safety of other chromosomes, the genetic decrease of the Y chromosome is a significant evolutionary phenomenon considered by wide gene loss and size reduction, leading to the accumulation of toxic mutations and the final loss of most Y-linked genes (14).

The Y chromosome is subject to degradation, with evidence of lineage-specific loss in some mammals. While it has added genes and shows signs of purifying selection, its overall size and gene content have significantly diminished over evolutionary time. (15)

The Y chromosome has lost many genes over time; retaining primarily those necessary for male sex determination .The implications of this process are profound, affecting not only male fertility but also broader evolutionary dynamics. (16)

As a concern to the evolutionary studies, the Y chromosome has been regularly losing its genetic material over time, this make us wonder about its future fate. If the trend lasts, the Y chromosome could eventually become destroyed, which would have insightful effects on human health in reproduction and the persistence of the male sex (17)

Conclusion

The sex determination and fertility researches in human and many economic animals have focused

on the molecular and biochemical mechanisms of genetic behavior of genes on sex chromosomes but the variation have not yet been fully unstated in animal kingdom, some studies determined that the sex determination in advanced vertebrate ; birds and mammals is must be under the regulation of genes, also its obvious that the human SRY region on the Y chromosome is complicated in sex determination and many sexual defaults during embryogenesis of the organism. The upcoming of the Y chromosome has been a focus of strong discussion among researchers, with guesses of its potential loss varying widely. While some readings suggest that the Y chromosome may vanish within the next few million years due to ongoing degeneration, others indicate that it has stabilized and is unlikely to disappear imminently, therefore we need more information about fate of this chromosome to understand more facts about male health fertility and evolution secrets of human after many millions next years when we not be there.

References

1. Alexander, N., Combes., Cassy, M., Spiller., Peter, Koopman. (2010). Sex Determination and Gonadal Development. 27-79. Available from: 10.1002/9780470687970.CH2

2. Hake, L. & O'Connor, C. (2008) Genetic mechanisms of sex determination. *Nature Education* 1(1):25

3. Iannuzzi, V., Bacalini, M.G., Franceschi, C. *et al.* The role of genetics and epigenetics in sex differences in human survival. *Genus* **79**, 1 (2023). https://doi.org/10.1186/s41118-023-00181-1

4. Mukhopadhyay C.S, Gupta A.K, Yadav B.R, Khate K, Raina V.S, Mohanty T.K, Dubey P.P. Subfertility in males:An important cause of bull disposal in bovines. Asian Aust. J. Anim. Sci. 2010;23:450–455.

5. Haseltine P.F, Michael E, McClure M.E, Goldberg E.H. Genetic markers of sex differentiation. Psychology. 2013;3:107.

6. Bichile D.L, Kharkar A.R, Menon P, Potnis-Lele M, Bankar M, Shroff G.A. Y chromosome:Structure and biological functions. Indian J.Basic Appl. Med. Res. 2014;3:152–160

7. Hesamoddin, Sajadi., Neda, Taghizabet., Fereshteh, Aliakbari., Fatemeh, Rezaei-Tazangi., Mohammad, Ali, Sedighi, Gilani. (2021). 1. Effects of Y chromosome Microdeletions on Male Fertility. Available from: 10.22037/MHJ.V5I1.35135

8. Levi, S., Teitz. (2018). The effects of natural selection on human Y chromosome amplicons

9. Naoki, Okashita., Makoto, Tachibana. (2021). 1. Transcriptional Regulation of the Y-Linked Mammalian Testis-Determining Gene SRY.. Sexual Development, Available from: 10.1159/000519217

10. Thomas, Ohnesorg., Andrew, H., Sinclair. (2013). 4. Sex Determination, Human. Available from: 10.1016/B978-0-12-374984-0.01402-9

11. Joseph, D., Racca., Deepak, Chatterjee., Yen, Shan, Chen., Ratan, Kumar, Rai., Yanwu, Yang., Millie, M., Georgiadis., Elisha, Haas., Michael, A., Weiss. (2022). 1. Tenuous transcriptional threshold of human sex determination. II. SRY exploits water-mediated clamp at the edge of ambiguity. Frontiers in Endocrinology, Available from: 10.3389/fendo.2022.1029177

12. Jean D. Wilson, The Role of Androgens in Male Gender Role Behavior, *Endocrine Reviews*, Volume 20, Issue 5, 1 October 1999, Pages 726–737, https://doi.org/10.1210/edrv.20.5.0377

13. Olaf, Hiort. (2013). 5. The differential role of androgens in early human sex development. BMC Medicine, Available from: 10.1186/1741-7015-11-152

14. Manfred, Schartl., Dunja, K., Lamatsch. (2023). 1. How to manage without a Y chromosome. Proceedings of the National Academy of Sciences of the United States of America, Available from: 10.1073/pnas.2218839120

15. Darren, K., Griffin. (2012). 6. Is the Y chromosome disappearing?--both sides of the argument.. Chromosome Research, Available from: 10.1007/S10577-011-9252-1

16. Przemyslaw, Biecek., Stanislaw, Cebrat. (2008). 2. Why Y chromosome is shorter and women live longer. arXiv: Populations and Evolution, Available from: 10.1140/EPJB/E2008-00325-4

17. Gutiérrez-Hurtado IA, Sánchez-Méndez AD, Becerra-Loaiza DS, Rangel-Villalobos H, Torres-Carrillo N, Gallegos-Arreola MP, Aguilar-Velázquez JA. Loss of the Y Chromosome: A Review of Molecular Mechanisms, Age Inference, and Implications for Men's Health. Int J Mol Sci. 2024 Apr 11;25(8):4230. doi: 10.3390/ijms25084230. PMID: 38673816; PMCID: PMC11050192.